Students' Ability in Solving TIMSS Problems through Realistic Mathematics Education

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Abstract. The abstract should summarize the contents of the paper in short terms, i.e. 150-250 words The Trends in International Mathematics and Science Study (TIMSS) is an international-based assessment used to assess students' mathematical skills. Previous TIMSS results showed the Indonesian students' mathematics skills are alarming. Teachers should improve students' ability to deal with TIMSS problems with a proper teaching approach, one of which is Realistic Mathematics Education (RME). This study aimed to determine students' ability to solve TIMSS problems using the RME approach. This study employed a quantitative approach. The design used is pre-experimental, a one-shot case study. The study population was all students from 11 classes at one of the Islamic junior high schools in Banda Aceh, Indonesia. The sample was selected by purposive sampling, resulting in 36 Year 8 students. The instrument was a test consisting of five long answer problems. Data were analyzed using the t-test. The results showed that student's ability to solve TIMSS problems after experiencing learning with the RME approach reached the advanced category. Therefore, the RME approach is a feasible alternative learning approach to improve students' mathematical abilities.

Keywords: Problem-Solving Skills, Realistic Mathematics Education (RME), Trends In International Mathematics And Science Study (TIMSS).

1 Introduction

The Trends in International Mathematics and Science Study (TIMSS) stands as one of the global assessments utilized to evaluate students' proficiency in mathematics. TIMSS is designed to gauge the knowledge and skills of students in mathematics and science, particularly those in Grades 4 and 8. Indonesia is among the numerous countries taking part in TIMSS, aiming to benchmark its students' mathematical and scientific proficiency against their global counterparts [1]. TIMSS findings unveiled a concerning trend in the mathematical abilities of Indonesian students. In the 1999 TIMSS assessment, Indonesia scored 403, falling below the international average of 487 and securing 34th out of 38 participating countries [2]. Subsequent assessments continued to depict subpar performance, with an average score of 411 in 2003 (ranking 35th out of 46 countries) and 397 in 2007 (ranking 36th out of 49 countries) against an international average of 500 [3, 4]. In 2011, Indonesia's score further declined to 386, persisting in 2015 with a score of 397 [5, 6]. Remarkably, Indonesian students dedicate

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173 hours to mathematics study, ranking third globally after Ghana, whereas the international average study time is 138 hours per year. The TIMSS (2015) outcomes underscored that Indonesian students exhibit lower proficiency in solving mathematical problems than international standards.

Addressing the challenge of low student proficiency is crucial. Implementing treatments that familiarize students with problem-solving in everyday scenarios is essential to tackle this issue. One effective learning approach for this purpose is Realistic Mathematics Education (RME). Originating from Dutch mathematicians and educators, notably Freudenthal at the Freudenthal Institute [7], RME emphasizes understanding and problem-solving, steering away from rote memorization. It initiates the learning process with problems drawn from students' daily lives that are easily imaginable. RME perceives mathematics as a human activity [8], and Freudenthal's perspective [9] encompasses both horizontal and vertical mathematization. In the horizontal approach, students utilize mathematical concepts to address real-world challenges. At the same time, vertical mathematization involves restructuring within the mathematical framework, leading to shortcuts derived from interconnected concepts and strategies.

Students, guided by teachers, can discover mathematical concepts and apply them to real-life problems. The essence of RME aligns with the pressing need to enhance mathematics education in Indonesia, particularly in elevating students' understanding of mathematics and nurturing their reasoning abilities [10]. This underscores the significance of RME as a viable solution, especially for improving students' Higher Order Thinking (HOT) skills in the Indonesian mathematics education landscape.

Prior research has consistently demonstrated the effectiveness of the Realistic Mathematics Education (RME) approach in enhancing students' problem-solving skills and cognitive achievements. RME has been involved in a longstanding reform in mathematics in the Netherlands and internationally in various projects concerning mathematics education, including problem-solving and reasoning [11]. A previous study utilizing the Connect, Organize, Reflect, and Extend Realistic Mathematics Education (CORE RME) model emphasized the importance of cognitive styles and teaching models in enhancing students' problem-solving ability [12]. RME approach outperforms conventional methods in enhancing students' mathematical problem-solving skills [13]. Another study [14], focusing on 50 junior high school students in Ambon, Indonesia, revealed a substantial difference in cognitive achievement. Students taught with RME achieved significantly higher average scores than their conventionally taught counterparts.

Several studies have explored students' abilities in Indonesia in solving TIMSS problems [15][16]. However, these studies were conducted without any specific treatment. Researchers are keen on further investigating students' ability to solve TIMSS problems through the RME learning approach. This effort aims to enhance the overall quality of learning, producing high-achieving students, particularly in the context of TIMSS problems. Additionally, the findings offer valuable insights for teachers, facilitating improvements in learning outcomes in future educational endeavors. This study will ascertain students' abilities in solving TIMSS problems using the RME approach.

2 Methods

This study employed a quantitative approach, one-shot case study. In this study, treatment was carried out for a group and the results were observed. The population of this study was all students from 11 classes at an Islamic Junior High School in Banda Aceh, Indonesia. Meanwhile, the sampling was done by purposive sampling, resulting in one class of Year 8 consisting of 36 students.

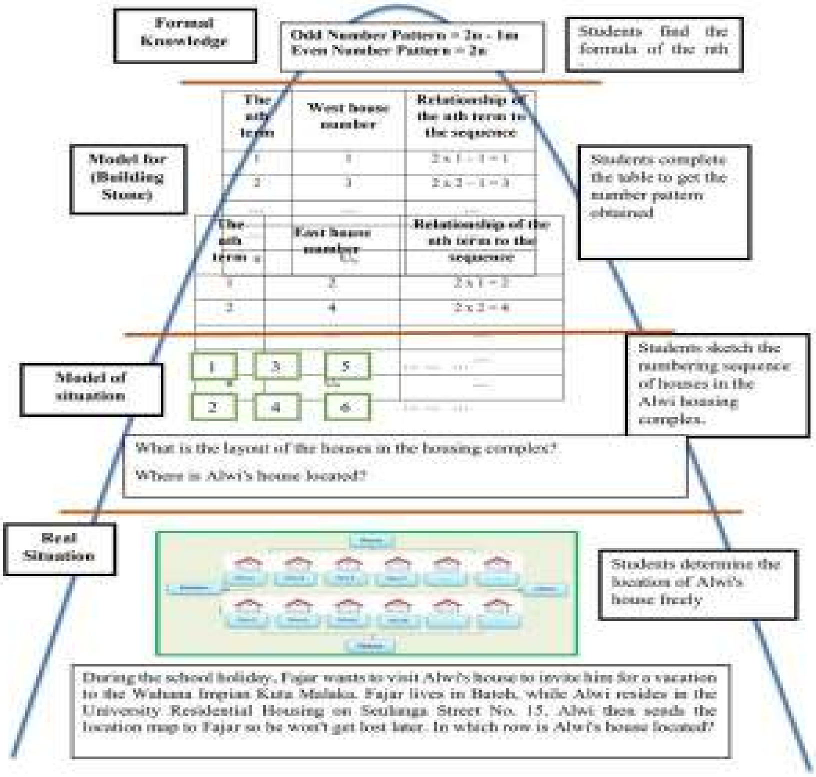


Fig. 1. Learning trajectory.

The instrument in this study was a test consisting of three items from TIMSS 2011 and two items from TIMSS 2019. These problems have been validated internationally and translated into Indonesian. The test obtained an overview of students' problem-solving skills. Other instruments were lesson plans and worksheets, developed directly by researchers and validated by experts in the respective field. The researchers also made a learning trajectory for each meeting to support the learning process. The material taught with RME learning is number pattern. Fig. 1 presents one of the learning trajectories used in this research. Learning trajectories are useful as guidelines for implementing learning and an anticipation of possible problems students face in the learning process [17].

The research data was obtained through a test after the treatment with the RME approach. This study required four meetings: three meetings for treatment and one meeting for the test. After the data was collected, students' test answers were assessed using the guidelines for scoring problem-solving skills. The student's score was converted into the TIMSS international scale with the formula:

$$H = \left(\frac{ST}{SM} \times 700\right) + 100$$

Were:
H = Student's final score
ST = Total score obtained by students
SM = The highest possible score students get

The data was tested for normality, as a requirement of the t-test. Data normality testing was needed to determine whether the data obtained from student test data was normally distributed. The test was carried out using SPSS 25. After the data was tested for normality, the data was tested for the following hypothesis.

H0 : $\mu < \mu 0$ Students' ability to solve TIMSS problems through the Realistic Mathematics Education (RME) approach has not yet reached the advanced category.

H1 : $\mu \geq \mu 0$ Students' ability to solve TIMSS problems through the Realistic Mathematics Education (RME) approach reached the advanced category

3 Results and Discussion

3.1 Results

The research was conducted at an Islamic Junior High School in Banda Aceh, Indonesia. The data for this study were derived from the student's performance in solving TIMSS problems following the application of the RME approach. A test was administered after three sessions of learning with the RME approach. Table 1 provides descriptive statistics detailing the results of the student test scores.

Table 1. Descriptive statistics of student test results

	Test Scores
Mean	675.94
Standard Error	9.679
Median	681

Variance	3372.911
Standard Deviation	58.077
Minimum	576
Maximum	772
Range	196
Skewness	-0.114
Kurtosis	-1.028

Table 1 presents descriptive statistics on the results of the student's mathematical problem-solving skills test in Grade 8 (36 students) (M=675.94, SD=58.077). The next data analysis was the prerequisite test before testing the hypothesis, the normality test. It was performed using SPSS 25. The normality test results can be seen in Table 2.

Table 2. Test results for normality of test data

	Test Scores
Asymp. Sig. (2-tailed)	.200[c,d]

Test distribution is Normal

Table 2 shows the results of the normality test and indicates that data is normally distributed (p=0.00). After the prerequisite test was fulfilled, the t-test was performed using SPSS 25 and the results are presented in Table 3.

Table 3. t-test result

	Test Scores
T	5.263
Df	35
Sig. (2-tailed)	0.000

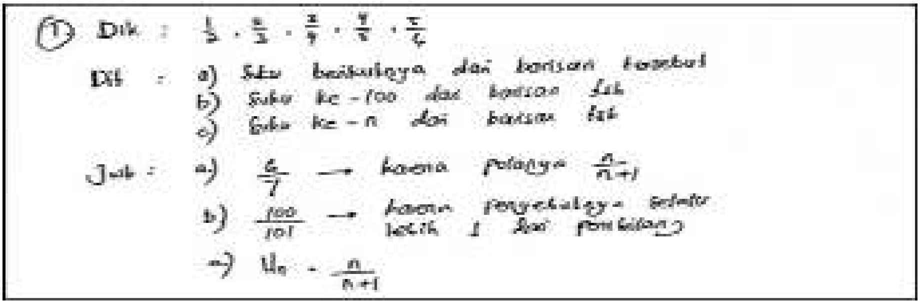
Table 3 presents the results of the t-test, indicating a significant difference between the test and the minimum criteria of advance category (t (35)=5.263, p=0.00). Hence, H0 is rejected and H1 "the ability of students to solve TIMSS problems through the Realistic Mathematics Education (RME) approach to reach the advanced category", is accepted

3.2 Discussion

This study assessed students' proficiency in solving TIMSS problems by applying the RME approach. The research involved applying the RME approach as a treatment, spanning three sessions. The treatment was administered following the developed lesson plan. The teaching and learning process adhered to the procedural steps outlined in the RME approach. The effectiveness of the RME learning model in enhancing problem-solving abilities can be attributed to its syntax. This includes: 1) presenting contextual problems to reinforce the first problem-solving indicator, understanding the problem; 2) teachers observing students' answers without prior input, aligning with the second and third problem-solving indicators, where students can plan and execute problem-solving; and 3) teachers encouraging students to engage in peer discussions, supporting the fourth problem-solving indicator, the re-examination process of accomplished results. Each phase of RME learning aligns with and reinforces problem-solving indicators [12].

During the RME-based learning sessions, students engaged in group discussions to enhance the enjoyment and meaningfulness of the learning process. This enabled students to effectively communicate their work results and exchange ideas. Students collaboratively explore contextual problems, reconstructing models through schemes, diagrams, symbols, and other means. The completion of RME-designed worksheets aims to fulfill the problem-solving indicators. Following the treatment, students undergo a test to assess their proficiency in solving TIMSS problems. Analysis of the test responses reveals that most students successfully answered the problems in line with the problem-solving indicators. For instance, MA subjects achieved high marks.

In Problem 1, the MA subject accurately documented what was known and what was asked in the problem. MA subjects demonstrated proficiency in problem-solving, obtaining correct answers, and providing reasons for each solution.



Given :

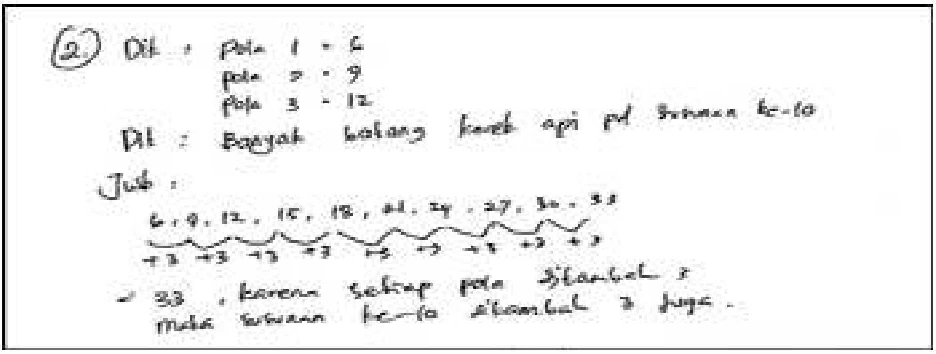
Find:
a) the next term of the sequence,
b) the 100th term
c) the nth term

Solution:

because the denominator is always the numerator plus one

Fig. 2. Answers of subject MA for problem 1

In Problem 2, the MA subject wrote down what was known and what was asked from the problem correctly. The subject of MA planned a solution and carried it out in a directed manner so that the correct solution was obtained. The MA subject also wrote down the reasons and how to get the solution.

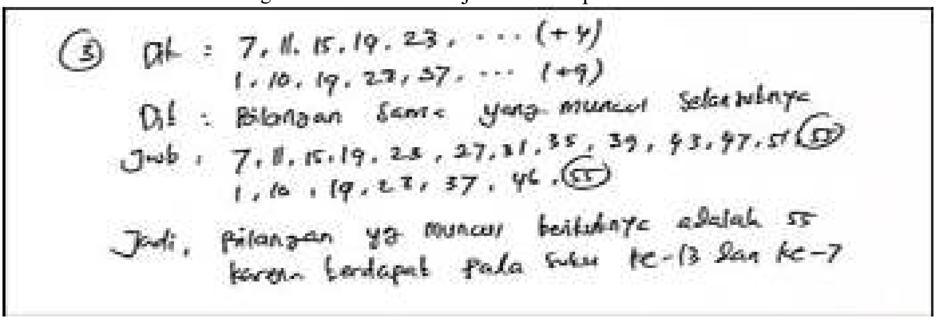


Given:
Pattern 1 = 6, Pattern 2 = 9, Pattern 3 = 12

Find:
The number of matches at the 10th row

Solution:
33, because each pattern is added by 3, so the 10th row should be added by 3.

Fig. 3. Answers of subject MA for problem 2



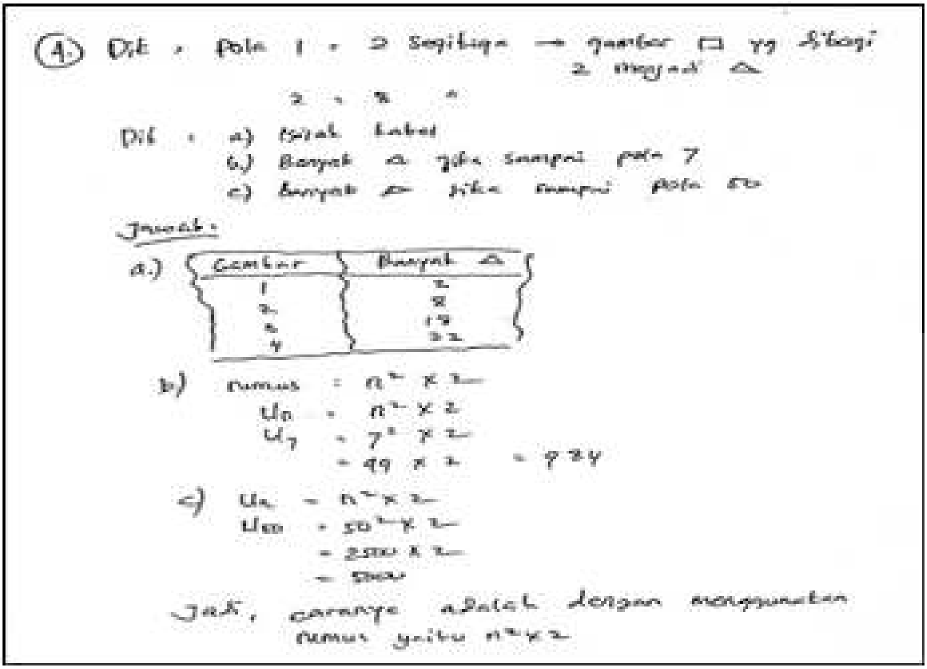
Given:
7, 11, 15, 19, 23 .....(+4)
1, 10, 19, 22, 37 ..... (+9)

Find:
The same number in the next pattern.

Solution:

Fig. 4. Answers of subject MA for problem 3

In Problem 3, the MA subject again wrote down what was known and what was asked correctly. The subject of MA carried out the correct steps to obtain the correct results. MA subjects also wrote conclusions from their answers.



Given:
Pattern 1: 2 triangles (the rectangle divided by 2)
Pattern 2: 8 triangles

Find:

Fill in the table.
The number of triangles after 7^{th} term
The number of triangles after 50^{th} term

Solution:
As in the figure

The problem can be solved using the formula of

Fig. 5. Answers of subject MA for problem 4

In Problem 4, the MA subject accurately documented what was known and what was asked from the problem correctly. The MA subject strategically devised and executed a solution, yielding the correct answer. Furthermore, the MA subjects adeptly articulated conclusions drawn from their responses.

The MA subjects demonstrated a coherent connection between what was asked and what was known. They systematically implemented the problem-solving plan, employing accurate mathematical operations at each step. The process for each stage was meticulous, and the MA subjects systematically re-evaluated the problem, culminating in well-formulated conclusions. Thus, it is deduced that MA subjects satisfy all problem-solving indicators. This finding aligns with previous research [18], which emphasized enhancing problem-solving abilities through the RME approach. Similarly, the results echo another research's finding [19], emphasizing the RME approach as a significant contributor to fostering effective problem-solving skills. However, it is noteworthy that some students, such as the AT subject, did not meet all the problem-solving indicators, which is evident in their comparatively lower scores than their peers

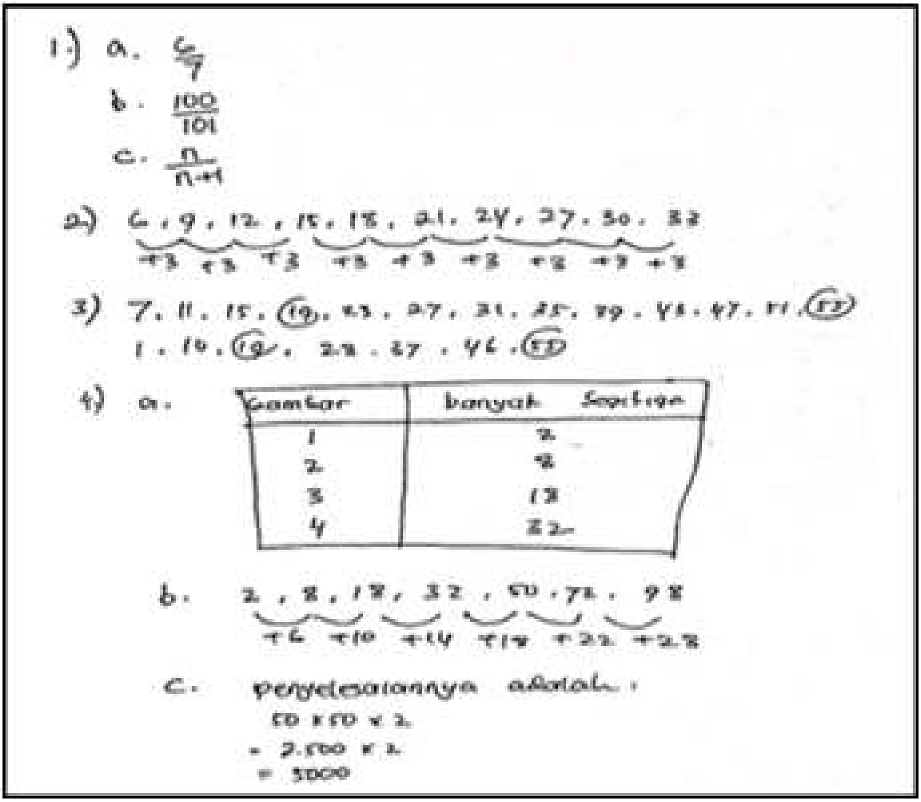


Fig. 6. Answers of subject AT for problem 1

It is evident from Figure 6 that AT did not specify what was known and what was being asked in the problems. Despite this, the AT subject successfully solved the problems and obtained accurate results. The AT subject, however, did not provide a conclusion for the answers. Therefore, it can be stated that the AT subject did not meet all the problem-solving indicators. Some students fail to complete problem-solving adequately due to neglecting to re-check the provided information and the arithmetic operations used [13].

The final test results yielded an average score of 675.94 (Median =681, and SD= 58.077). Subsequently, the normality test concluded that the data on student learning outcomes were normally distributed. The final analysis technique employed was the independent sample t-test. It was determined that there was a significant difference in the students' scores after the treatment (p=0.00). Therefore, it can be concluded that H0 is rejected, and H1 is accepted. It can be inferred that students' ability to solve TIMSS problems through the Realistic Mathematics Education (RME) approach reached the advanced category.

The results of this study indicate that students' mathematical problem-solving abilities through the RME approach can reach the advanced category based on the TIMSS benchmark. Providing treatment using the RME learning approach makes students more active during the learning process and better master the material provided as they convey it directly to their peers [20].

The advantages of the RME learning model, such as being based on real conditions, can motivate students to study harder because they perceive learning mathematics as useful [21]. Abstract mathematical concepts are more easily comprehended by students based on contextual problems in their real-life [22]. Another study emphasized the importance of real context and the influence of culture in it [23]. During the learning process using the RME learning approach, they collectively identify what is known and what is asked in the problems, create strategies for solving problems, and draw conclusions together, resulting in a much lower error rate during tests. RME influences the success of the learning process and is appropriate by problem-solving indicators, thereby enhancing students' problem-solving skills.

4 Conclusion

The analysis concludes that students' ability to solve TIMSS problems through the RME approach reaches the advanced category (very high). RME can be employed as an alternative learning approach to enhance students' mathematical problem-solving skills. For future research, it would be beneficial to explore the long-term impact of sustained RME implementation on students' mathematical proficiency and to investigate the effectiveness of RME in diverse educational and content settings. Additionally, assessing the transferability of RME principles to other content related to TIMSS problems could provide valuable insights into its broader pedagogical implications.

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